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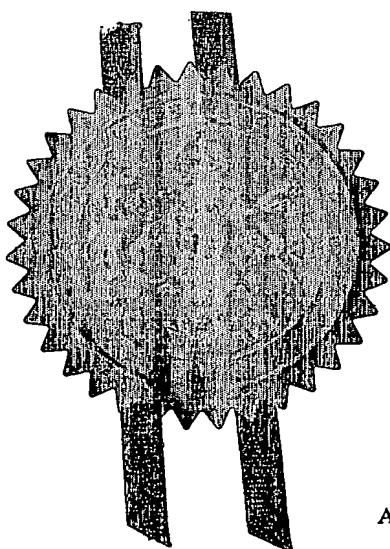
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Signed *H.Bekker*

Dated 27 November 2003

An Executive Agency of the Department of Trade and Industry

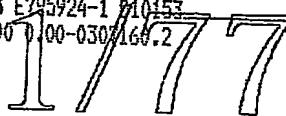
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28MAR03 E795924-1 P10153  
P01/77001 00-030/L69.2



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The Patent Office

Cardiff Road  
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NP10 8QQ

#### 1. Your reference

P169-GB

#### 2. Patent application number

*(The Patent Office will fill in this part)*

0307160.2

#### 3. Full name, address and postcode of the or of each applicant (underline all surnames)

1... Limited

St John's Innovation Centre  
Cowley Road  
Cambridge CB4 0WS

8113870001

Patents ADP number *(If you know it)*

If the applicant is a corporate body, give the country/state of its incorporation

England

#### 4. Title of the invention

CERAMIC ACTUATOR AND LOUDSPEAKER

#### 5. Name of your agent *(If you have one)*

Akram K. Mirza

"Address for service" in the United Kingdom to which all correspondence should be sent  
*(including the postcode)*

1... Limited  
St John's Innovation Centre  
Cowley Road  
Cambridge CB4 0WS

Patents ADP number *(If you know it)*

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#### 6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(If you know it)* the or each application number

Country      Priority application number  
*(If you know it)*      Date of filing  
*(day / month / year)*

#### 7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application      Date of filing  
*(day / month / year)*

#### 8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*

YES

- a) *any applicant named in part 3 is not an inventor, or*
- b) *there is an Inventor who is not named as an applicant, or*
- c) *any named applicant is a corporate body.*

*See note (d))*

## ( Patents Form 1/77

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Description	7
Claim(s)	2
Abstract	1
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10. If you are also filing any of the following, state how many against each item.

## Priority documents

## Translations of priority documents

## Statement of inventorship and right to grant of a patent (Patents Form 1/77)

## Request for preliminary examination and search (Patents Form 9/77)

Request for substantive examination  
(Patents Form 10/77)Any other documents  
(please specify)

11.

I/We request the grant of a patent on the basis of this application.

Signature

Date 28-MAR-03

12. Name and daytime telephone number of person to contact in the United Kingdom

Akram K. Mirza

01223-422290

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P169-GB

**CERAMIC ACTUATOR AND LOUDSPEAKER****FIELD OF THE INVENTION**

The present invention relates to loudspeaker systems for  
5 portable electronic devices such as mobile phones, personal  
digital assistants (PDAs) and laptop computers. More  
specifically, it relates to a method and system for generating  
low frequency or vibratory signals and higher acoustic  
frequency or audible signals. Furthermore it relates to such  
10 systems driven by actuators based on piezoelectric materials.

**BACKGROUND OF THE INVENTION**

In mobile communication and data processing equipment, the  
generation of audible sound, buzz tones or vibration are  
15 handled by systems mostly driven by electro-magnetic  
actuators.

Sound is usually generated by, albeit small, voice-coil driven  
loudspeakers, whereas number of reasonably inexpensive and  
20 effective constructions have evolved for providing signal  
units to generate the necessary tones or vibrations for these  
devices. These include miniature motors with imbalanced rotors  
to create a sensible vibration; small piezoelectric assemblies  
to vibrate at an audio frequency and create a tone or beep  
25 ("buzz") noise; and other, older technologies such as speakers  
with an electromagnetic voice coil, or a magnetic solenoid  
driving a diaphragm to create a sound such as an audio tone or  
a vibratory buzz. Many of the current mobile phones use  
separate components for vibration alert, audio alert and  
30 speech or music reproduction.

Also, it is desirable for most portable devices to have a  
"hands-free" mode, i.e., a mode that allows a user to  
communicate through the device without having to use his or

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her hands. In order to operate portable phones in a hands-free mode, a high power output is required over a frequency range of 300 to 3400 Hz, often referred to as the speech band. At present the hands-free mode of commercially available products  
5 is exclusively implemented through common electro-dynamic or moving coil loudspeakers.

A number of piezoelectric alerting devices have been proposed to generate a vibration or non-audible alert or audio  
10 frequency vibration and, thus, constituting a speaker. Examples of such devices are described in the United States Patent Nos. 5,514,927; 5,368,456; 6,078,126 and 6,169,206.

15 In the commonly-owned published international patent application WO-03/001841, which is incorporated herein by reference, there are described various devices and methods to generate sound comprising a support on which is mounted an electro-active actuator, which is in turn coupled to an area-extensive section of the case of the device, which section of  
20 the case acts as the sound generating element of a loudspeaker. In embodiments illustrated therein the sound generating element is driven in operation by an electro-active actuator preferably acting upon an edge of the sound generating element. The actuator described is a flat ceramic bender curved into an almost tubular shape.  
25

30 It is the purpose of the present invention to provide a improved electro-active drive unit for loudspeaker for use in for example electronic devices, particularly portable electronic devices such as mobile phones

#### SUMMARY OF THE INVENTION

Accordingly, in a first aspect the present invention provides a loudspeaker for a possibly portable electronic device such

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as a mobile phone which comprises a support on which is mounted one or more electro-active actuators, which is in turn coupled to an area-extensive section of the case of the device, which section of the case acts as the sound generating element of the loudspeaker, wherein the actuator or actuators include a curved section and at least one flat section.

The curved section is preferably formed having a hollow cylindrical shape with one sector extending along the longitudinal axis of the cylinder being removed. Hence a cross-section perpendicular to the longitudinal axis is a section of a circle or in other words C-shaped. At the longitudinal extending ends the curved section into one or more flatter sections that provide contact or mounting points to mount the actuator onto the support structure. A perpendicular cross-section through flat and curved section of the actuator thus resembles a flat-lying question mark or the Greek letter  $\Omega$ , depending on whether a flat section terminates one or both ends of the curved section.

It is advantageous to provide flat sections to facilitate the mounting of the ceramic actuator onto support structure or sound generating surface or both.

However, an additional advantage is seen in providing a curved actuator that has sections at which the curvature of the material changes from inward bowing (concave) to flat or outward bowing (convex).

These and other features of the inventions will be apparent from the following detailed description of non-limitative examples making reference to the following drawings, throughout which like parts are designated by like reference numerals and characters.

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## BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

5

FIG. 1A is a perspective top view of an actuator in accordance with an example of the invention;

10

FIG. 1B shows a cross section through the actuator of FIG. 1A;

FIG. 2 is a perspective top view of a variant of the novel actuator;

15

FIG. 3 is a perspective top view of another variant of the novel actuator; and

FIGS. 4A,B illustrate a loudspeaker driven by an actuator as shown in FIG. 1.

20

## DETAILED DESCRIPTION

In FIG. 1A, there is shown a perspective view of the novel actuator 10. The main elements of the actuator include a convex curved section 11. The single convex section 11 changes curvature to form an intermittent concave section 12 before extending gradually and continuously into an essentially flat section 13. The actuator 10 is manufactured from multi-layered ceramic tape 101 with layers of ceramic PZT separated by 25 layers of electrodes (not shown). The numbers of such layers are determined by the manufacturing process and can range from 30 two ceramic (PZT) layers to more than ten.

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The tape can be produced in accordance with well known manufacturing techniques. In its green state, it is then cut and pressed onto a suitable former to give it the form shown in FIG. 1A. Then the tape is burned out and sintered at high 5 temperatures (600 to 1200 degrees Celsius). Outer electrodes may be applied after the sintering. After a poling step the actuator is ready to be mounted onto a chassis. These manufacturing steps are known per se and are regarded to be well within the scope of person skilled in the art.

10

A schematic cross-section through the actuator 10 of FIG. 1A along the line AB is shown in FIG. 1B. The first curved section 11 is convex, whilst the second section 13 is essentially flat. Between the two sections, there is a portion 12 where the curvature changes from convex to concave. The 15 convex and concave portions of the actuator are indicated by dashed circles reflecting their respective main radii R1 and R2 of curvature. The multi-layered tape making up the actuator acts essentially as a bender with different portions moving in different directions as indicated by arrows in FIG. 1B. As the 20 first curved section 11 moves essentially radial, the flat portion 13 and the intermediate concave portion 12 move upwards. The combined motion of the distal end 111 of the actuator is indicated by arrow 14. It is an essentially 25 vertical movement with lesser components of the motion in undesired tangential directions compared to known actuators such as the C-shaped actuator of WO-03/001841. The rotational displacement of the known C-shaped actuator of WO-03/001841 is similar to the motion of the first curved section 11, however 30 in the case of the novel actuator 10 it is partly cancelled by the concave section 12, resulting in an improved or "purer" vertical displacement of the distal end 111.

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The example of FIG. 2 shows a variant of the previous example modified in that the flat section 23 includes two tabs or lead-outs 231. In other words, a rectangular section is cut out of the flat portion 23, thus reducing the amount of active material necessary to implement the actuator 20 while at the same time preserving the advantageous properties of the novel actuator design as described herein. Thus, other elements 21, 22 of the actuator and its motion and displacements of the actuator of the present example is essentially identical to those illustrated in FIG 1B above.

I

The two tabs 231 provide a sufficiently large area to mount the actuator onto a flat surface and electrical terminals to connect the actuator to an electronic drive circuit and power supply.

For some applications, it may be useful in and advantageous to terminate the distal end of the actuator with the second flat portion. This second flat portion, though not contributing significantly to the displacement, could facilitate the mounting of the distal (moving) end of the actuator onto an movable object such as a loudspeaker diaphragm.

In FIG. 3 such an actuator 30 is shown. In addition to the convex section 31, the flat section 33 and the intermediate portion 32 shared with the above examples, the actuator 40 has a flat portion 34 at its distal end.

In FIG. 4, the actuator of FIG. 1 is shown used as a drive unit 40 to drive a rectangular diaphragm 44 within the housing 45 of a mobile device. The diaphragm material is Perspex™ (poly methylene methacrylate). The diaphragm 44 rests within a recess of the housing so as to be mounted flush with the outer surface of the housing 45.

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The gap between the housing 45 and the diaphragm 44 is sealed off by means of a compliant gasket 46 shown in FIG. 4B which is a cross-section of the perspective view of FIG. 4A along the line AB. It The gasket 46 prevents the entry of dust or humidity. It is made of Poron (TM), a cellular urethane based sealing material. The actuator 40 bridges the gap between the housing 45 and the diaphragm 44 at one short side of the rectangular diaphragm. The flat portion 43 of the actuator is mounted onto the housing while the curved portion 41 spans the sealed gap. The distal end 411 of the actuator is glued onto the diaphragm material 44.

When an operating voltage is applied to the actuator 40, the displacement drives the edge of the diaphragm 44 which in turn generates audible sound.

The larger contact area between the actuator 40 and the housing 45 together with the improved displacement of the actuator generate a higher sound level and an improved performance of the device as a loudspeaker compared to known devices such as described in WO-03/001841.

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## CLAIMS

1. Loudspeaker for audible sound comprising a sound emitting element mounted onto a support structure and at least one ceramic bender-type actuator being mounted at a proximate edge onto said sound emitting element and a distal edge onto said support structure, wherein the actuator comprises a first curved section extending radially into a second, essentially flat section.  
5
2. The loudspeaker of claim 1 having a compliant sealing element or elements around the edges of the sound-emitting element.  
10
3. The loudspeaker of claim 1 wherein the second flat section with the distal edge is mounted onto a part of the support structure while the first curved section with the proximate edge is mounted onto the sound-emitting element such that said curved section bridges a gap between said sound emitting element and said support structure.  
15  
20
4. The loudspeaker of claim 1 wherein the support structure and the sound generating element are parts of the outer shell of a portable data handling or communication device.  
25
5. The loudspeaker of claim 1 wherein the second flat section extends in a longitudinal direction into a rectangular shape.  
30
6. The loudspeaker of claim 1 wherein the second flat section terminates as two or more flat portions.

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7. Ceramic actuator comprising a first curved section extending radially into a second, essentially flat section.
- 5        8. The ceramic actuator of claim 7 having a single curved section bowed inwardly with a short outwardly bowed portion that extends into the flat section.
9. The ceramic actuator of claim 7 formed from a continuous sheet of piezoelectric material.  
10

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ABSTRACT

A loudspeaker for audible sound, and a drive unit, is described having a sound-emitting element mounted onto a support structure and ceramic actuator made of piezoelectric material that includes a curved portion that extends radially into an essentially flat section.

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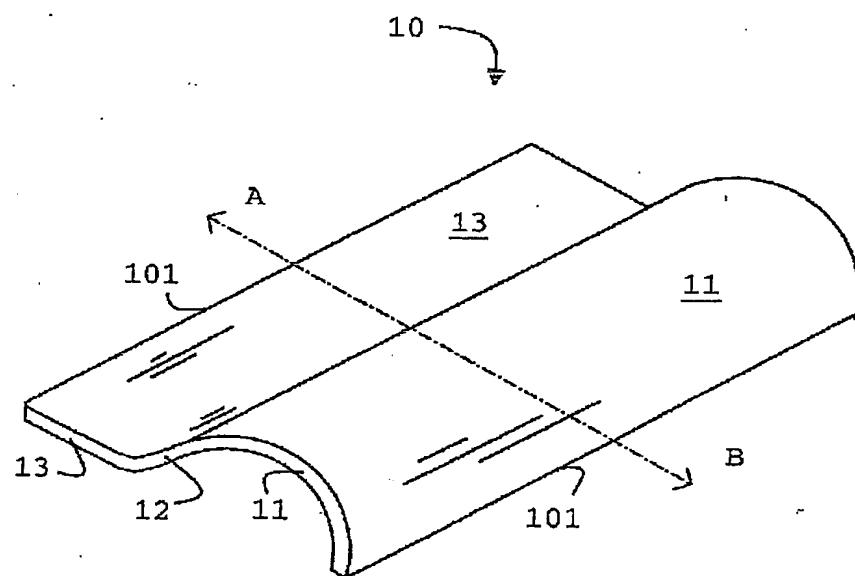


FIG. 1A

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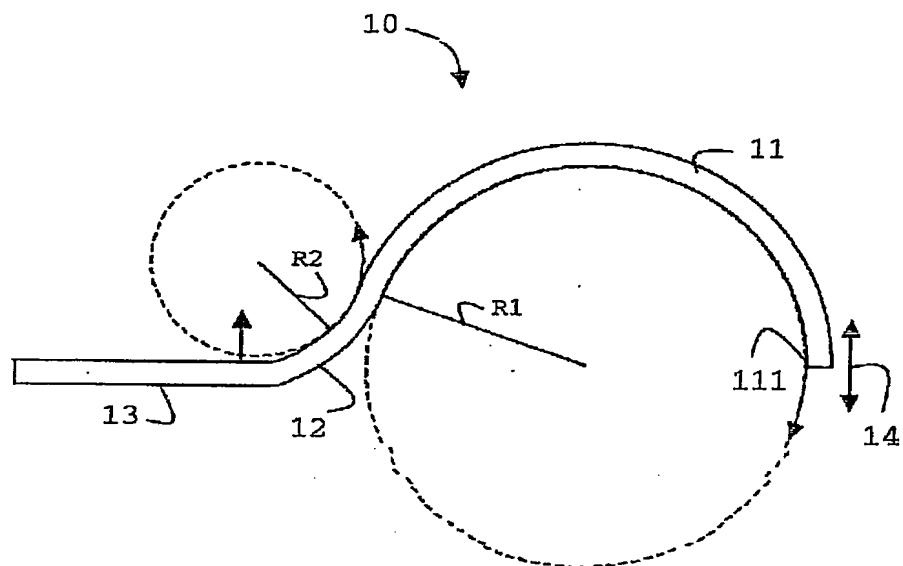


FIG. 1B

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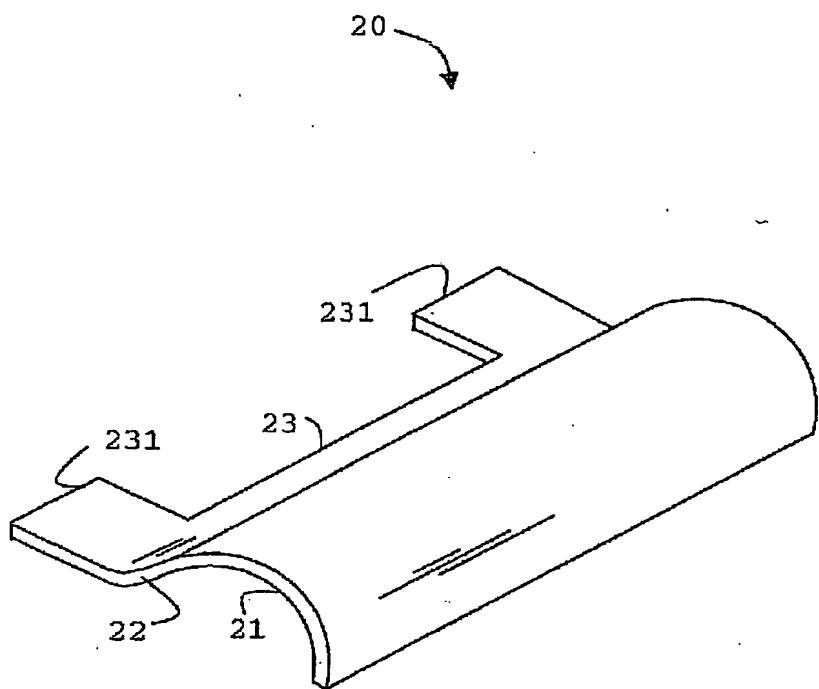


FIG. 2

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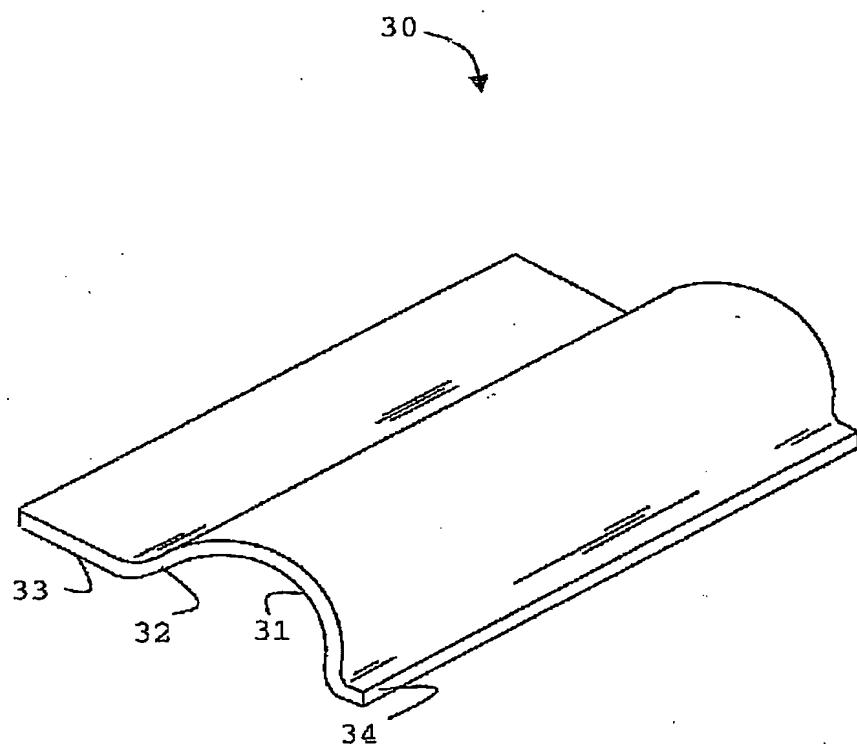


FIG. 3

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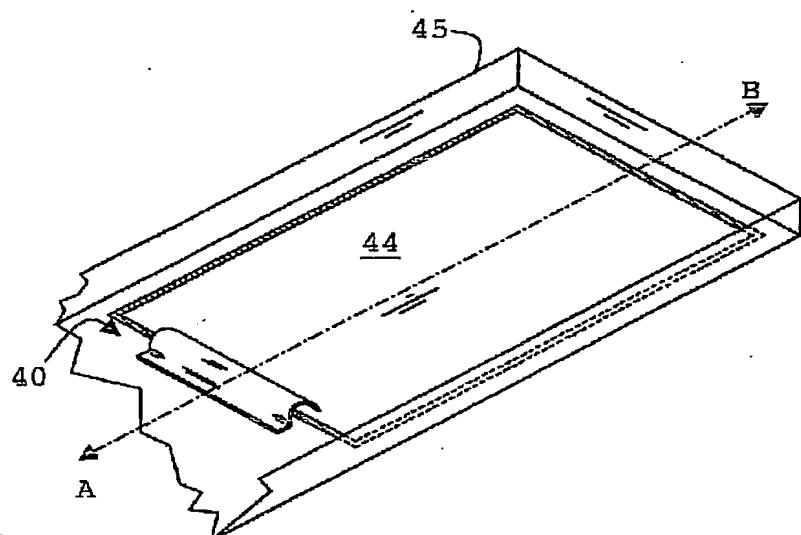


FIG. 4A

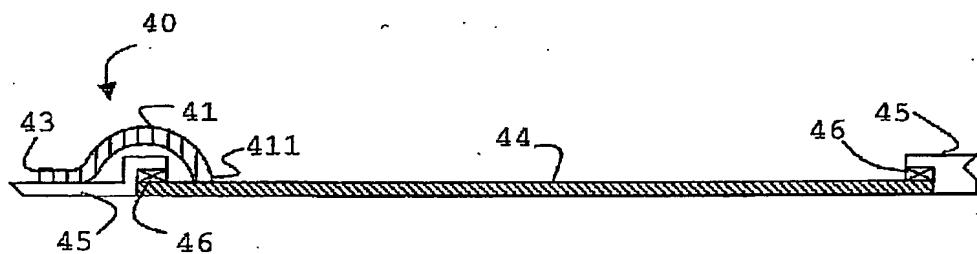


FIG. 4B

PCT Application

**GB0304862**



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